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1225 Section: \_\_\_\_\_  
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Date: \_\_\_\_\_

## Continuous Charge Distributions – Lab Activities

*Work through this handout and hand it in at the end of the laboratory period*

### Purpose

Calculate the electric field due to two different continuous charge distributions using numerical integration with spreadsheets.

**Apparatus**    Computer

### Problem 1 Field of a uniformly charged rod on a perpendicular bisector

Start Excel. Three worksheets are automatically opened. Work on Sheet 1 for this problem.

We are going to calculate the numerical value of electric field on a perpendicular bisector of a thin rod with 4 nC positive charge uniformly distributed on it. We will slice the rod into 10 equal pieces, find the position of each piece, calculate the electric field due to each piece and sum the field up.

#### Rows 1 through 11:

Copy the first 11 rows as shown in Fig 1. What should you type in cell C10 and C11? Refer to the “Spreadsheets Basics” in your prelab if you don’t know how to type a formula.

#### Rows 12 and higher:

Column A contains the slice #. Instead of typing in “1, 2, 3...”, we can use formulas:

A14: 1                                      First slice # is 1  
A15: =A14+ 1                              Next slice # is previous # increased by 1

and copy A15 into cells A16 through A23.

Column B has the positions, or more exactly,  $x$  coordinate of the slices.

B14: =\$C\$11                               $x$  coordinate of the 1<sup>st</sup> slice  
B15: =B14+\$C\$10                              Next slice is  $\Delta x$  away from the previous slice

Copy B15 into cells B16 through B23. Check that the numbers from B14 to B23 make sense. Why do we need a relative address for B14 but an absolute address for C10?

Column C is the electric field of each slice, but the constant factor  $kQy_p/L$  is not included.

C14:  $=\$C\$10/(\$C\$7^2+B14^2)^{1.5}$

Copy C14 into cells C15 through C23.

Finally, in column F, we sum the fields from all the slices, and then multiply the constant factor to get  $E_{\text{sum}}$ .

F13:  $=\text{SUM}(C14:C23)$                       sum of the contributions of each piece  
F14:  $=F13*C9*C5*C7/C6$                       the electric field, with the constant factor ( $kQy_p/L$ ) in  
F15:    exact result from analytical expression  
F16:  $=\text{ABS}((F14-F15)/F15)*100$                       percent discrepancy from the exact result

The exact numerical value for the electric field is given by the analytical integration result. See your prelab for that formula. Copy it to the box below, convert it into cell addresses, and enter it into cell F15.

Express $E_y$ with $k$ , $Q$ , $y_p$ and $L$ , then with the expression with the appropriate cell addresses:  $E_y =$  F15:
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Now you should have a functioning worksheet that looks similar to Fig 1. Replace ??? with the appropriate spreadsheet calculations.

	A	B	C	D	E	F	G
1	1225 Lab						
2	Problem 1: Electric field on a perpendicular bisector of a thin rod						
3							
4	Quantity	symb	value	Unit			
5	total charge	Q	0.000000004	C			
6	length	L	1	m			
7	field point	$y_p$	0.25	m			
8	number of slices	N	10				
9	Coulomb constant	k	8990000000	Nm <sup>2</sup> /C <sup>2</sup>			
10	length of slice	dx	???	m			
11	position of 1 <sup>st</sup> slice	$x_0$	???	m			
12							
13	slice #	x	$dx/(y_p^2+x^2)^{1.5}$		Sum =	28.64424	1/m <sup>2</sup>
14	1	-0.45	0.7330459339		E <sub>sum</sub> =	257.51176	N/C
15	2	-0.35	1.2567312297		E <sub>exact</sub>	???	N/C
16	3	-0.25	2.2627416998		% diff =	???	%
17	4	-0.15	4.0352608269				
18	5	-0.05	6.0343426196				
19	6	0.05	6.0343426196				
20	7	0.15	4.0352608269				
21	8	0.25	2.2627416998				
22	9	0.35	1.2567312297				
23	10	0.45	0.7330459339				
24							

Fig 1

Modify your spreadsheet to a 20-piece, then a 60-piece calculation. Write your results in the table below. Check that your results make sense!

# of pieces	$E_y$ (N/C) (Keep 8 digits.)	% diff with exact value
10		
20		
60		
Exact Value		—

### Question 1: Accuracy of the numerical result

When you increase the number of slices, did your numerical value of  $E_y$  get closer to or further from the exact value?  Closer  Further

For the rest of the questions, use your 20-slice calculation.

Make the length of the rod 0.01 m instead of 1 m. Is your numerical value of  $E_y$  closer to or further from the exact value?  Closer  Further

Explain your answers above, referring to the physics. (Hint: what assumption is the numerical integration method based on?)

### Question 2: Relative contributions of the slices

Change the length of the rod back to its original value.

Insert a column or bar chart of the entries in column C. (Select the appropriate cells in column C and then choose “Chart” from the “Insert” menu.)

Which slices contribute more to the total field?  End slices  Middle slices

Change the field point to be much further away. Do the end pieces become more or less important in the sum?  More  Less

Explain your answers above, referring to the physics.

When you have finished all of the above, have an instructor initial here:

Initials of the instructor: \_\_\_\_\_

## Problem 2 Field of a uniformly charged rod on axis

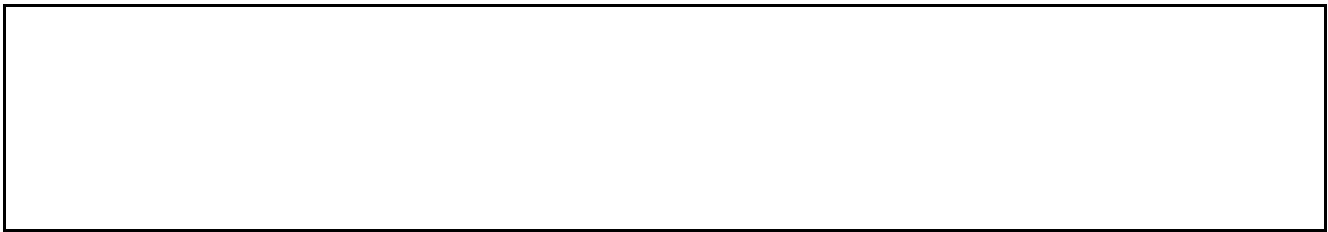
In this problem, you are going to construct a spreadsheet very similar to the first problem, but with your own formulas.

Copy Sheet 1 to another worksheet in the same file and work on this sheet for Problem 2.

A uniformly charged thin glass rod of length  $L$  and total charge  $Q$  is lying on the  $x$ -axis with one end at the origin. What is the electric field at a location  $P$  on the  $x$  axis where  $x_P > L$ ? Let  $L = 1$  m,  $x_P = 1.5$  m and  $Q = 5$  nC.

You should have already solved this problem in your prelab before coming to the lab. You are asked to reproduce some of that work here.

Draw the diagram here again. Clearly show your coordinate system and field point  $P$ . Cut up the charge distribution into 10 pieces, pick a representative piece and mark its position  $x$ . Also mark  $r$ , the distance from the representative piece to the field point, and  $\overline{\Delta E}$ , the electric field vector due to the representative piece at the field point  $P$ .



For the representative piece, write its charge  $\Delta q$  and field  $\Delta E_x$  in terms of  $k$ ,  $Q$ ,  $L$ ,  $x_P$ ,  $x$  and  $\Delta x$ . Sum up all 10 pieces to find the field  $E_x$ . Move the constants  $k$ ,  $Q$ , and  $L$  in front of the summation symbol\*. Write down exactly what you will enter in cells C14, F13 and F14 (similar to the top of page 2).

$$\Delta q =$$

$$\Delta E_x =$$

$$E_x = \Sigma \Delta E_x =$$

C14:

F13:

F14:

\* But we will keep  $\Delta x$  after the summation symbol because  $\Delta x$  turns into  $dx$  when the sum turns into an integral.

Based on your prelab, write the analytical expression of the field in terms of  $k$ ,  $Q$ ,  $L$  and  $x_P$ . Convert it into cell address format and write it down too. It will go to cell F15.

$$E_x = \int \frac{k dq}{r^2} =$$

F15:

Using the spreadsheet, calculate the numerical value of the electric field  $E_x$ . Start with 10 pieces. Write your results in the table below. Increase the number of pieces until your value is consistent with the exact value to 4 digits. (It would be a good idea to get an instructor to check your result for 10 pieces first.)

# of pieces	$E_x$ (N/C) (Keep 8 digits.)	% diff with exact value
10		
20		
50		
( )		
Exact Value		—

After you finish all of the above, have an instructor initial here:

Initials of the instructor: \_\_\_\_\_

When you are done, close the program and turn off your computer.